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AIDS
FOR INCREASING DIESEL ENGINE LIFE
and
ANALYSIS OF FAILURES

GUARDIAN
MAINTENANCE

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INTRODUCTION

This brochure suggests procedures for engine users to follow in order to minimize engine failures and emphasize what can be learned from such failures when they do occur. The points considered in this brochure are as follows:

A. CYLINDER HEAD FAILURE ANALYSIS.

B. FACTORS THAT AFFECT CRANKSHAFT LIFE.

C. GETTING THE MOST OUT OF CYLINDER COMPONENTS.

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GENERAL MOTORS CORPORATION

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AIDS FOR INCREASING ENGINE LIFE AND ANALYSIS OF FAILURES

Points Considered In This Brochure:

A. Cylinder Head Failure Analysis.
B. Factors That Affect Crankshaft Life.
C. Getting The Most Out of Cylinder Components.

A. CYLINDER HEAD FAILURE ANALYSIS

THE "PLUS SIDE" DEFINED

Replacing a damaged cylinder head is a bitter pill for anyone to swallow. But there is a plus side to this experience. It lies in what can be learned through an analysis of the removed head and an investigation of the conditions leading to its removal and what can be done to avoid a repeat in the future. Toward this worthwhile end, this section of the brochure has been prepared.

Too often persons faced with a cracked cylinder head conclude that design was lacking, but cylinder head failure is usually a secondary failure. It is caused by the cooling system failing to remove fast enough the heat being generated in the combustion chamber, which causes the cylinder head to expand abnormally against its bonds and crack.

The cooling system removes about 25% of the total heat generated in the combustion chamber, which is approximately 1100 BTU's per minute per cylinder in a Detroit Diesel engine with N60 injectors operating under maximum load. This is enough heat to bring one gallon of water at room temperature to a boil in one minute. Much of this heat passes through the metal in the cylinder head to the cooling system. Overheating of the cylinder head metal is usually caused by improper preventive maintenance procedures that allow the engine to operate with:

INSUFFICIENT COOLANT

A cylinder head fire deck will overheat and fail in a short operating time if the coolant does not cover the fire deck surface. Coolant level below the top of the radiator core admits air bubbles to the system displacing coolant at heat transfer surfaces, air locking the water pump and reducing coolant flow.

RUST, SCALE, AND SEDIMENT
ACCUMULATIONS IN THE COOLING SYSTEM

These foreign particles act as an insulator on the water side of the cylinder head fire deck, slowing heat transfer.

RESTRICTION OF COOLANT FLOW

Restriction of coolant flow on the suction side of the water pump will promote air leakage at the water pump seal.

DIRT AND DEBRIS ON THE
RADIATOR CORE EXTERIOR

An unkept radiator core exterior can reduce air flow slowing heat transfer from the coolant to the air.

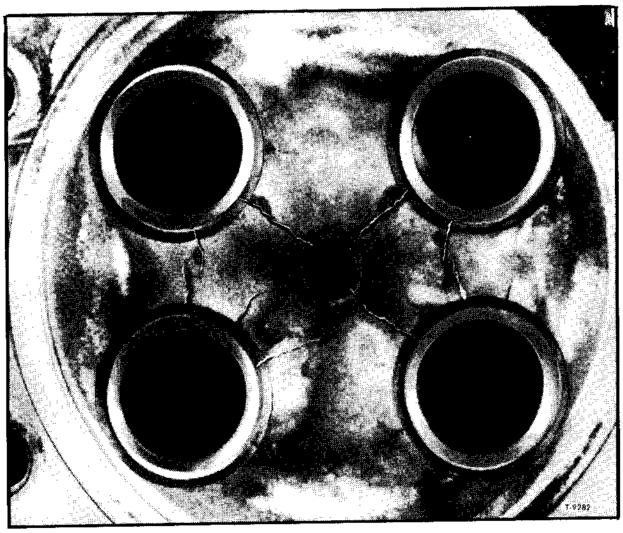
SLIPPING FAN DRIVE BELTS

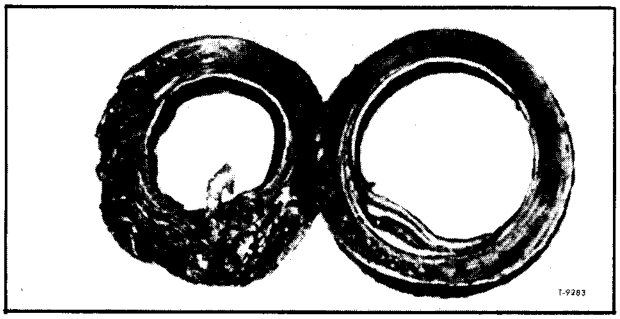
Slipping fan belts can cause overheat by reducing the air flow through the radiator.

FIVE TELL-TALE SIGNS THAT INDICATE OVERHEATING WAS THE CAUSE OF THE CYLINDER HEAD FAILURE

CRACKS

- Running from valve to valve, from water hole to bolt hole, from injector tube to valve, or sun-burst cracks at the valve seat counterbore.

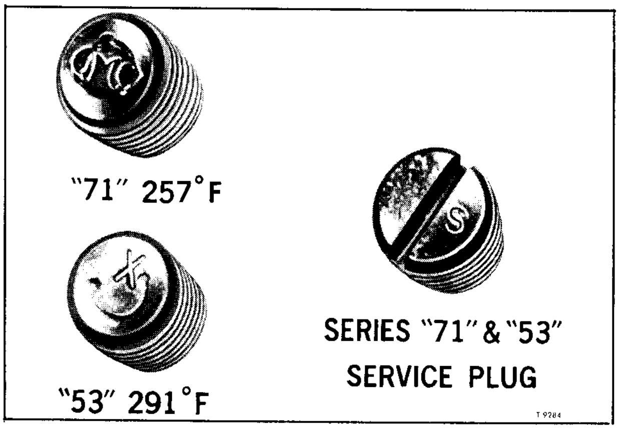




DETERIORATION OF HEAD TO BLOCK SILICONE SEALS

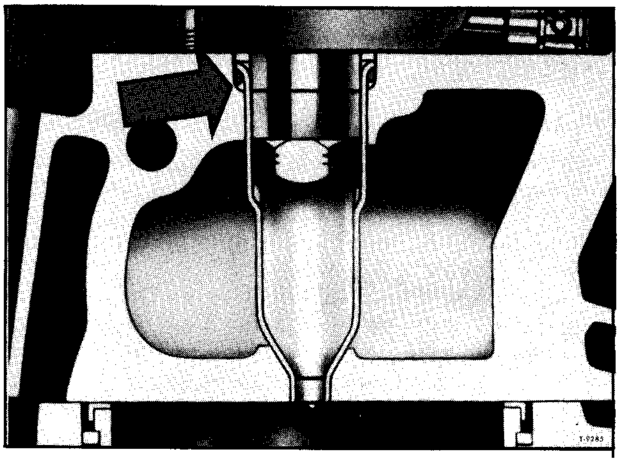
- Which is evidenced in three stages:

1. The seals become mushy on the I.D. from contact with steam.
2. Material flakes off in sections as if it were laminated.
3. The seals harden, crystallize and finally start to disintegrate as the heat becomes more intense and steam is replaced by dry heat.



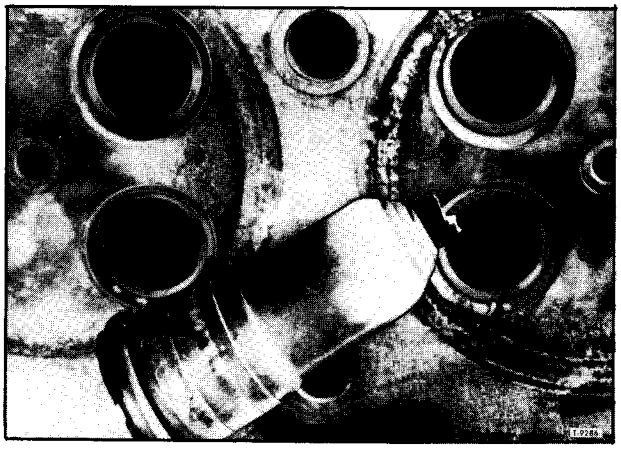
MELTED FUSE PLUG

- Located on the exhaust manifold side of the cylinder head. Inspection of the fuse plug requires its removal from the head except in the Detroit Diesel In-line and V-71 engines.



CONDITION OF INJECTOR TUBE SEAL RINGS

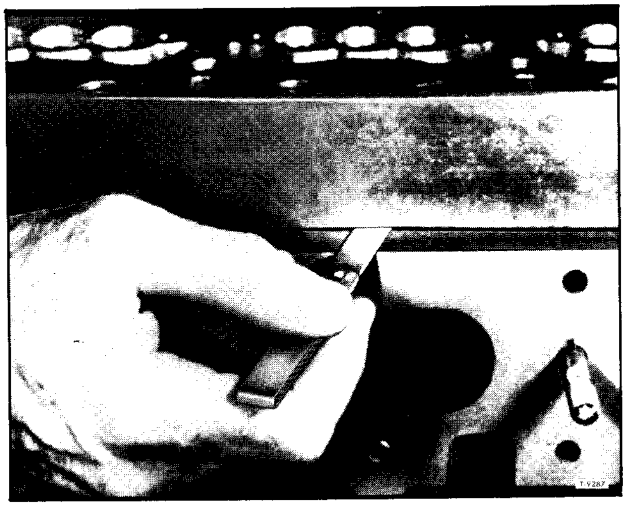
- Which become brittle when exposed to high temperatures.



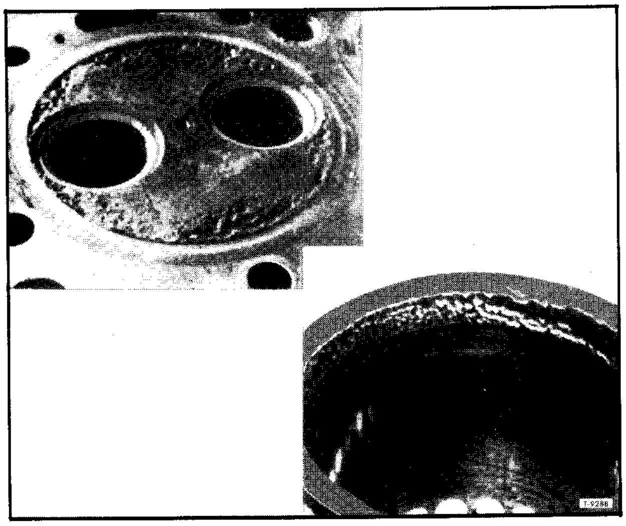
APPEARANCE OF THE INJECTOR HOLE TUBE

- Which may show evidence of blow-by or a high heat condition, destruction of the injector hole tube seat in severe overheat, or excessive water usage by the accumulation of deposits.

OTHER SIGNS OF CYLINDER HEAD OVERHEATING ARE:



WARPAGE
- A warped cylinder head.



PITTING
- Fire deck, liner and piston crown pitting resulting from the entry of water in the cylinder by damaged combustion chamber components.

IMPORTANT: Cylinder head overheating is generally caused by an inadequacy in the cooling system. Correct the primary cause, the cooling system inadequacy, before placing the unit back into service.

COOLING SYSTEM CARE

The engine cooling system is made up of components that function to release engine heat in the manner illustrated.

To enable all components to function at peak efficiency, steps should be taken each spring and fall to reduce the formation of rust and scale on heat transfer surfaces, to insure good circulation inside the engine and to promote efficient dissipation of heat at the radiator.

CARING FOR THE ENGINE COOLING SYSTEM

CHECKING FOR COOLING SYSTEM LEAKS

Trace the entire cooling system for leaks. Minor ones are usually the toughest to detect. Make the necessary corrections.

Coolant loss that occurs on a regular basis is made serious by the fact that scale, most common to unfiltered systems, is formed from mineral in the water which settles out as the water is repeatedly heated and cooled. The more water entering the cooling system, the greater the build-up of scale on the internal cooling surfaces of the engine.

An abnormal build-up of scale on these surfaces hampers heat transfer, resulting in increased operating temperature of the cylinders. This condition can compound until major engine repairs are required.

FLUSHING THE COOLING SYSTEM

Just as common sense dictates that antifreeze should be added to the engine prior to cold weather, it makes good sense to remove the antifreeze for the warm weather. The inhibitors in "permanent" antifreeze can become depleted during winter and/or the system can become contaminated. Start by opening the drain cocks and flushing the old cooling solution from the system. If the coolant shows excessive rust and scale, use a reputable and safe cleaner, being careful to follow the instructions for neutralizing the system afterwards. Continue to flush until clean water drains from the engine.

Following flushing, refill the system with clean water and a rust inhibitor in summer and an inhibited antifreeze in fall.

Check the radiator cap. Repeated loss of coolant may mean the pressure regulator valve is not operating properly. If the hoses tend to collapse, the vacuum relief valve may not be functioning within limits.

Check the thermostat (and replace the seals on blocking type thermostat). Submerge the "stat" into a pan of water and heat. The thermostats, most often used, start to open when the temperature reaches approximately 170°F., and are fully open at approximately 185°F.

CHECKING AIR FLOW

Clean the radiator externally to remove any lodged debris, grit and dust. Direct compressed air and flushing water through the radiator in a reverse direction to normal air flow and use a reputable cleaner if necessary. Continue the cleaning process until the radiator is clean.

CHECK:

- Radiator shrouds for proper fit.
- Radiator fan for damaged blades.
- Radiator shutters for proper opening and closing.

CHECKING FAN BELTS

Check for wear and cracks on the I.D. of the belts. Check for wear of the pulleys. Do not install new belts on badly worn pulleys. Check fan belt tension. Use a fan belt tension gauge and tension to the recommended value if necessary. Be sure there is no oil or water leakage on the belts.

B. FACTORS THAT AFFECT CRANKSHAFT LIFE

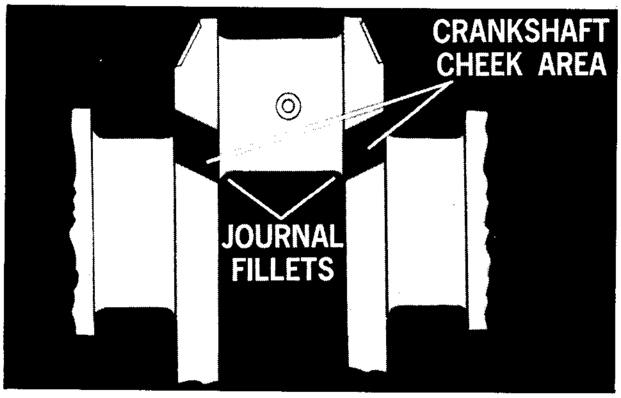
The primary function of the engine crankshaft is to convert the lineal travel of reciprocating pistons inside firing cylinders into rotary motion that is transferred to the output shaft as power for doing work.

In this capacity, the crankshaft must be able to give a little to absorb the firing impulses that provide the cranking force. It must also have the strength to endure and convey this power to the load forces placed on the output shaft. An awesome task certainly, but the crankshaft in a Detroit Diesel engine has the stamina to meet this task over many years -- providing the shaft is properly installed and supported in the block and the engine is applied, operated and maintained in a manner consistent with its power capabilities and prevailing work conditions.

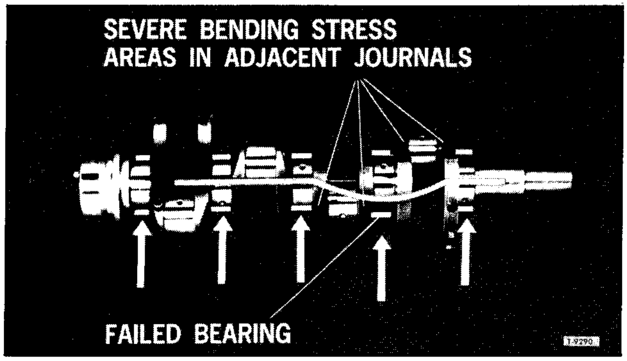
On the other hand crankshaft durability is severely tested when the shaft has to endure forces while rotating that cause it to bend or twist abnormally or subject it to excessive end-thrust forces.

This section of the brochure describes conditions inside and outside the engine that can materially shorten crankshaft life. It suggests procedures for engine users to follow on the job and in the shop to minimize their development.

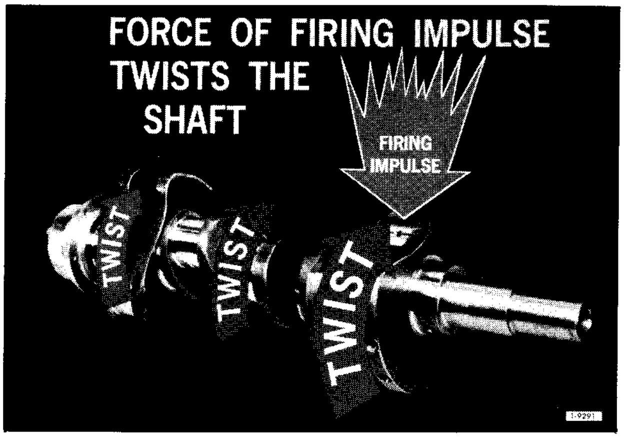
A CRANKSHAFT THAT BENDS OR TWISTS BEYOND NORMAL LIMITS WHILE ROTATING IS UNDER STRESS



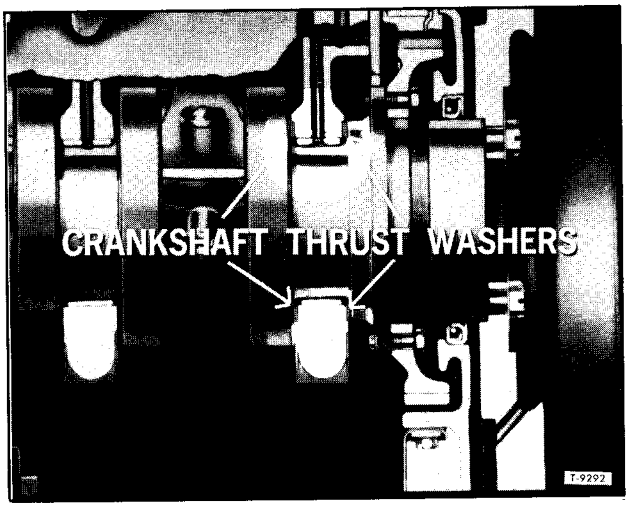
The areas of the crankshaft most susceptible to stress are the cheeks between the main and connecting rod journals and the rod journal fillets.



Conditions that impose severe crankshaft bending stress include inadequate bearing support, misalignment, or excessive side load on the front or rear of the shaft. Stress is greatest in the connecting rod journals next to the point of the bend. Fatigue starts at the rod journal and advances throughout the crank cheek, sometimes extending into the main bearing fillet.



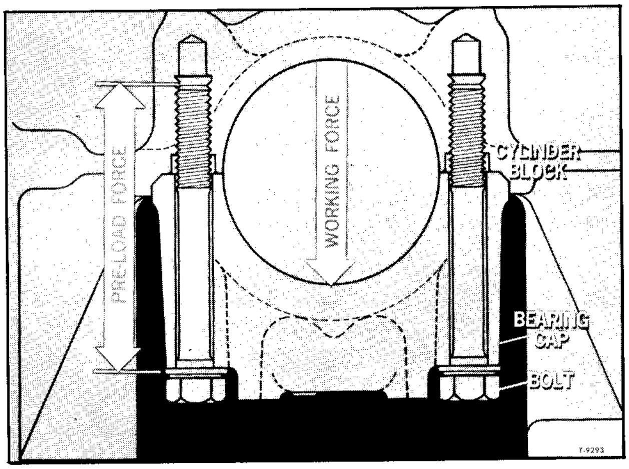
The twisting force of firing impulses on the crankshaft produces torsional vibrations. If exaggerated by engine overspeed or amplified by a faulty driven component, these vibrations can stress load the crankshaft connecting rod journals, particularly the fillets and oil holes. Fatigue cracks at these locations will usually run at 45° angles to the main axis of the crankshaft.



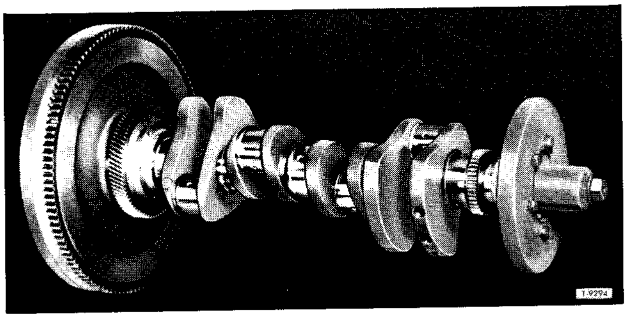
Excessive end-thrust force can remove the lubricating oil between the crankshaft and rear main bearing thrust washers subjecting the washers to rapid wear. The debris and heat from disintegrating thrust washers can "wipe out" main bearings, cause a loss of bearing support and subsequently impose a bending stress on the crankshaft.

SIX CONDITIONS THAT SHORTEN CRANKSHAFT LIFE

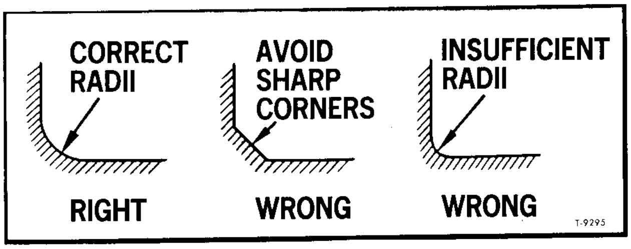
INSIDE THE ENGINE



A bad bearing or loose bearing cap caused by an improperly torqued bolt or an obstruction between the cap and block surface cannot support the crankshaft at that point. This will subject the shaft to bending stress.

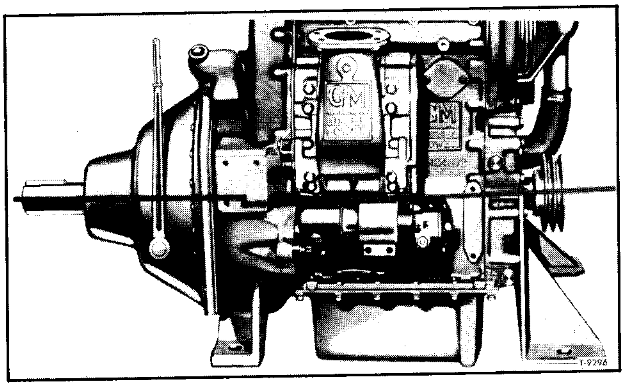


Overspeeding the engine can produce crankshaft vibrations that exceed vibration damper control. The undampened vibrations produce torsional stresses in the crankshaft particularly in the connecting rod journal areas.



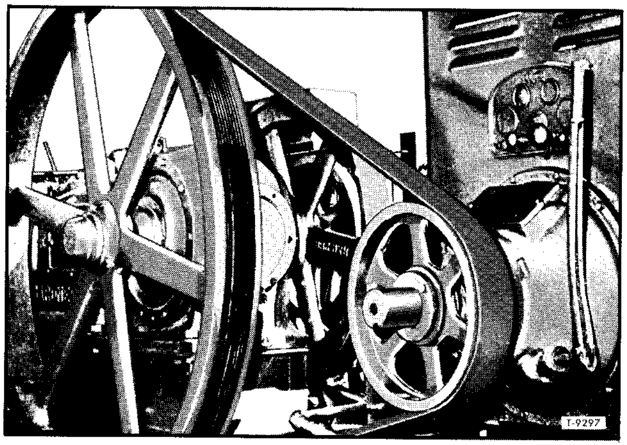
Sharp corners and insufficient radii at journal fillets and oil holes as a result of a poor regrinding job substantially weaken the crankshaft and increase the chance of fatigue when it is returned to service. A crack in any vital area of the crankshaft cannot be repaired or removed. Anything short of a magnaflux inspection of the entire crankshaft prior to regrinding is gambling with early shaft failure.

OUTSIDE THE BASIC ENGINE

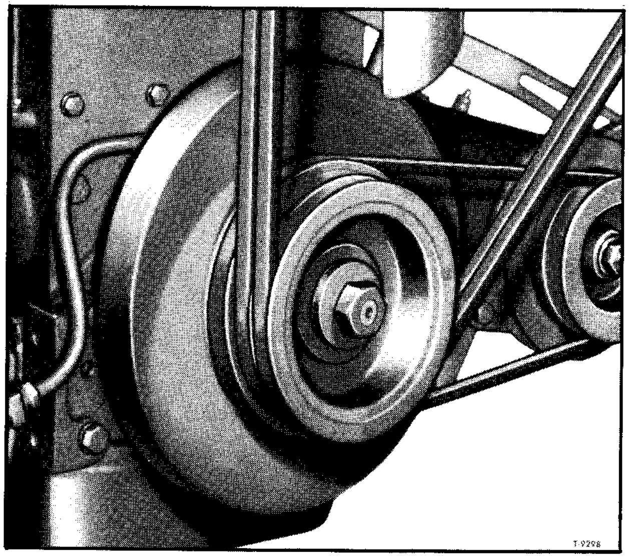


MISALIGNMENT OF ENGINE AND P. T. O.

A power take-off unit or a transmission that is poorly aligned to the crankshaft can sideload the crankshaft excessively and impose bending stresses in the shaft at the rear main bearing and connecting rod journal locations.



PTO drive belts if overtightened can side-load the output shaft and place a bending stress in the crankshaft at the rear main bearings. Overtightened accessory drive belts exert a similar force on the front of the crankshaft.



A vibration damper that is loose, damaged or improperly suited for the installation is unable to perform the job of controlling crankshaft vibrations and thus subjects the shaft to possible torsional fatigue. No damper where one is needed is equally damaging to the crankshaft.

SUGGESTIONS FOR EXTENDING CRANKSHAFT LIFE

ON THE JOB:

Here are some suggestions to remember when performing every day service on the engine . . . .

Crankshafts sometimes fail because dirt gets into the engine and lube oil as a result of careless engine servicing.

To keep dirt out of the engine and lube oil, be sure to clean the area around engine valve covers and the oil filler cap before removing them.

Also, use a clean container when adding lube oil to the engine. It takes only a small quantity of abrasive dirt to cause rapid wear of all bearing surfaces in the engine.

Some engines must have a vibration damper to keep torsional vibrations under control throughout the engine operating range. If a damper has become loose, inspect all components of the assembly for damage before tightening. A damaged, dented or leaking viscous damper must be replaced because it cannot perform its function. Further, a damper can become inoperative without showing signs of damage on the outside. Although a viscous damper cannot be thoroughly checked in the field, there is one test that will indicate if the damper has lost all its fluid. Remove the damper and shake it back and forth. A metallic rattling sound will indicate a loss of fluid and the damper must be replaced. However, the fact that a damper does not rattle is no test that it is serviceable. Regardless of condition, replace viscous type dampers at the time of major engine overhaul. Arrange to have a torsional analysis made of heavy front pulleys or couplings and large PTO's, generators or pulleys on the drive end when installed.

Operate the engine within the prescribed limits so as not to produce torsional vibrations which the damper is unable to control. Check governor and injector control linkage for improper travel or binding which can cause engine overspeeding.

IN THE SHOP:

The following crankshaft installation procedures are important to remember and include . . . especially after a crankshaft failure:

Carefully clean the interior of the block, all oil passages, the bearing caps and shell surfaces before installing the crankshaft. Clean the crankshaft thoroughly with fuel oil. Wire brush crankshaft oil passages. Check to be sure that all oil passage plugs are in place and tight after cleaning.

To be sure that bearing cap bolts will tighten down properly, check them for correct length and check the bolt holes for shallow threads and/or chips. Lubricate and tighten the cap bolts per the instructions given in the applicable Maintenance Manual.

Here is why bolt torque is important. When a bolt is properly torqued, it is stretched to a prescribed preload that exceeds the opposing work force of the component being retained. The preload force in the bolt must exceed the working force against it; otherwise, it can loosen, fatigue and break.

Be sure you check the crankshaft for freedom of rotation and end movement after it is installed.

Tighten all drive belts to the tension specified in the Maintenance Manual, and recheck belt tension at the intervals also given in the Maintenance Manual. Also, tighten the vibration damper retaining bolt using the method and the torque specified in the Maintenance Manual.

Adhering to Maintenance Manual procedures in all matters when installing a crankshaft will avoid building in a crankshaft failure.

Regrinding of a used crankshaft is best accomplished by a shop that specializes in such services.

All shaft fillets and oil hole radii must fall within the specifications shown in the applicable Engine Manual to prevent stress concentration.

The Maintenance Manual also describes the grinding procedures to be followed and specifies the journal surface finishes that are required.

Remember, before the regrinding job begins, a magnaflux inspection of the entire crankshaft is required. Be sure no grinding or magnaflux particles remain in any oil passages.

Be sure that high stress areas such as the crankshaft cheeks, journal fillets and oil hole radii are given a thorough inspection.

If there is a crack in any vital area, the crankshaft must be scrapped. A crack cannot be repaired or removed. Instead, a crack will continue to spread and will soon result in a crankshaft failure.

Being clean in all matters relating to the engine and exercising good judgment when matters of service arise pays off in longer life for all components of the engine.

C. GETTING THE MOST OUT OF CYLINDER COMPONENTS

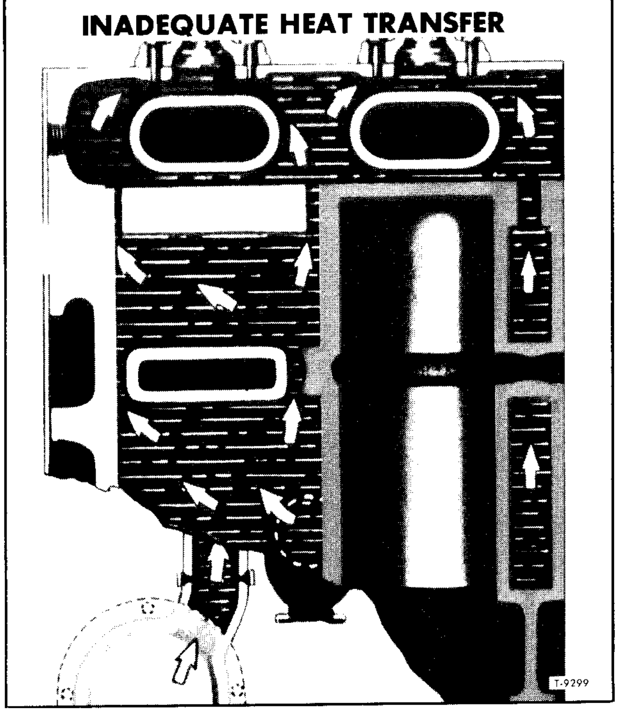
The cylinder liner provides a bearing surface for the piston . . . a sealing surface for piston rings. It admits air through inlet ports to the cylinder for combustion and exhaust scavenging and transfers cylinder heat to the cooling system.

The piston conveys the force of burning fuel through the connecting rod to the crankshaft, thus producing power. Compression rings provide a seal between the piston and liner as the piston moves up and down on the compression and power strokes . . . they also transfer some of the heat generated in the cylinder to the liner. Oil control rings regulate the lubricating oil left on the cylinder walls to prevent scoring.

The piston pin transfers power from the piston to the connecting rod. The piston pin rides in bushings that are pressed into the piston and the connecting rod and are internally grooved for lubrication. The pin rotates freely within the piston and rod bushings to permit the connecting rod to rock back and forth as the rod and piston move up and down with the rotating crankshaft.

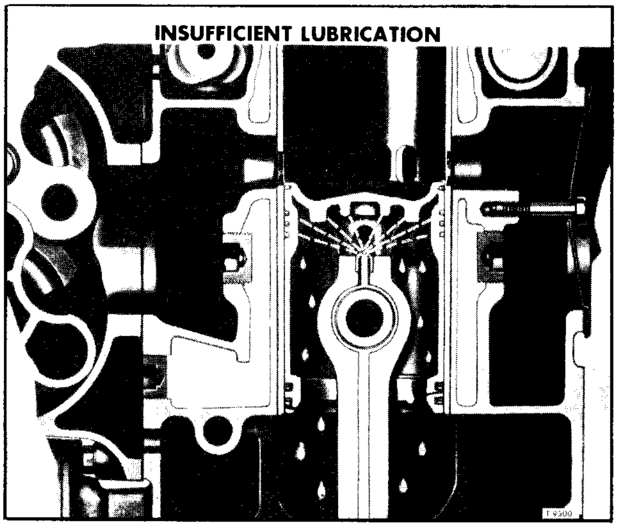
The connecting rod forms the link between the piston and the crankshaft. The rod is drilled through the center to lubricate the piston pin and pin bushings and to cool the underside of the piston.

Cylinder components are built strong to endure the force and heat of combustion -- but they also have polished bearing surfaces that function within thousandths (.000) of-an-inch clearances and demonstrate a limited appetite for extreme conditions of dirt and internal engine heat. In order for cylinder components to last, these bearing surfaces must be kept free of dirt and adequately cooled and lubricated at all times during engine operation.

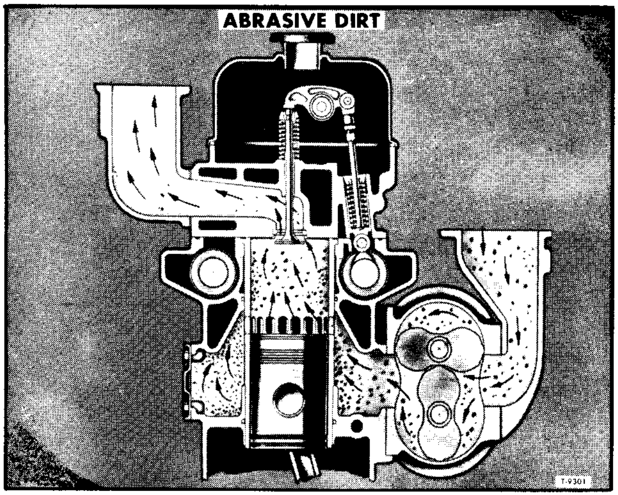


THESE CONDITIONS SPELL TROUBLE FOR CYLINDER COMPONENTS:

Conditions such as water jacket deposits or too little engine coolant can hinder heat transfer from the cylinder to the cooling system. If overheating results, the condition of the lube oil and the tolerances between parts are affected and cylinder components can score and possibly seize.



Dirt or other foreign particles that block the drilled passage of the connecting rod or the spray nozzle reduce oil flow to the piston, the piston oil flow to the piston, the piston pin and bushings. Without adequate oil, the lubrication between close fitting components is hampered and essential cooling is reduced.



Dirt that enters the engine via the air intake system deposits on the piston and liner surfaces. The reciprocating action of the piston together with the dirt and small amounts of oil form an effective lapping force which produces rapid ring and liner wear.

THE SOLUTION. . .ON-THE-JOB PM*

*PREVENTIVE MAINTENANCE HELPS TO PROMOTE A LONG, TROUBLE-FREE LIFE FOR ALL CYLINDER COMPONENTS

To get maximum life from cylinder components, keep the air, fuel, lubrication and cooling systems of the engine dirt-free and properly maintained. Inspect belts, pulleys, and gaskets frequently for wear and replace as needed to avoid unexpected delays.

COOLING SYSTEM

Check the coolant level daily and maintain it near the top of the radiator upper tank. Check hoses, hose connections, drain valves and gaskets for damage or excessive wear every 500 hours (15000 miles) and replace if necessary. If a visual inspection is inconclusive, pressurize the cooling system to five psi above radiator cap pressure and re-examine the area with a bright light.

Use inhibitors in the coolant to control corrosion and water jacket deposits. A non-chromate inhibitor system is recommended. Maintain inhibitor strength in accordance with the manufacturer's instructions. If a coolant filter is used, change the element every 500 hours (15000 miles). For freeze protection, use Ethylene-Glycol Antifreeze and re-inhibit as needed with a non-chromate inhibitor system. Complete coolant recommendations are provided in GMC Truck & Coach Service Information Bulletins.

LUBRICATING SYSTEM

Check the engine oil level daily before starting. When checking an engine that has just been shut down, allow 10 minutes for drainback.

The recommended lubricating oil for Detroit Diesel engines is S.A.E. #30 weight MIL-L-2104B or Supplement 1 oil with the following limitations:

1. Zinc, as zinc diorganodithiophosphate, between a minimum of 0.07 and a maximum of 0.10 per cent by weight.
2. Sulfated ash (ASTMD-874) of 1.00 per cent maximum by weight, except lubricants that contain only barium detergent-dispersants where 1.50 per cent by weight is allowed.

When initiating an oil change schedule for an engine, make the first change at 100 hours (the equivalent for highway vehicles is 3000 miles; for city service vehicles 1000 to 2000 miles). The drain interval may then be gradually increased or decreased, following the recommendations of an independent oil analysis laboratory or oil supplier (based upon an oil sample analysis) until the most practical oil change period has been established. Install new filter elements and gaskets with each change.

Combat dirt. Use a clean container to add oil to the engine. Before removing engine components for service, clean the surrounding area so that dirt does not drop into the opening. An in-frame overhaul is a timesaver but there is no way the block can be cleaned that compares to a hot tank cleaning.

Remember -- before starting a rebuilt engine the first time, it is necessary to pressure lubricate the engine oil gallery from an external source. Then the main and rod bearings will not be starved for oil while the pump works to charge the complete system.

AIR INTAKE SYSTEM

In order to protect the engine, the air intake system must be leak-proof.

Check the air cleaner and the duct work between the cleaner and the engine blower for leaks and replace damaged or deteriorated parts. Look for these conditions:

- Weld cracks at the cleaner outlet or in the duct work leading to the engine and at the mounting brackets.
- Stripped bolts on the cover clamps.
- Distorted seal grooves between the various components caused by dents in the cover, housing and pan.
- Damaged seals, caused through general deterioration.

Air cleaners are subjected to a considerable amount of vibration and rough handling to always remain air tight for the life of the engine. Frequent inspection is necessary.

All air intake systems impose a certain amount of inherent restriction on incoming air. When the engine is put to work and the air cleaner fills with filtered particles, the restriction grows. Without service, the air cleaner in time surpasses the restriction limit and engine performance is affected.

If not now in effect, establish a service schedule that permits maximum service life from the air cleaner element and/or filtering oil without exceeding the restriction limit of your engine(s). One way to accomplish this is to measure the air inlet restriction daily and record these readings in order to determine the proper change interval. Allow for a safety factor.

Heavy dust conditions on some jobs necessitate a change every 8 hours. Highway vehicle engines with a properly installed air system can go 6000 miles between air cleaner service. Some dry-type air cleaners feature an air restriction indicator that signals when service is needed. Be sure the instrument is functioning properly.

AIR CLEANER SERVICE

Refer to the proper Maintenance Manual covering the particular vehicle.

OIL BATH TYPE

Remove the dirty oil and sludge. If the sludge exceeds ½-inch, shorten service interval. Wash all parts in clean fuel oil and refill the cleaner to the level mark with the same oil as used in the engine.

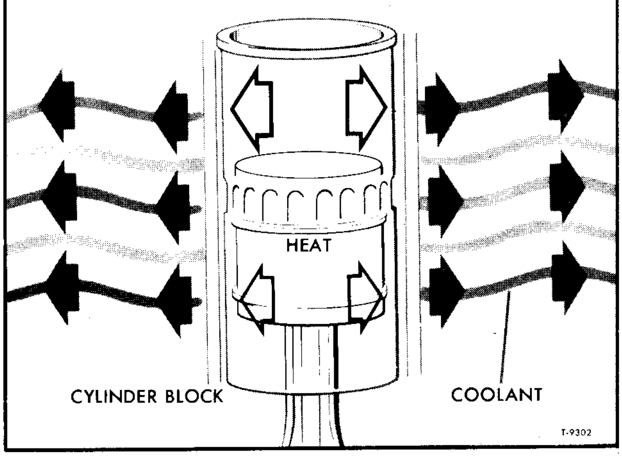
DRY-TYPE

Clean the inside of the cleaner housing and replace the element. Some elements are declared washable by the manufacturer. Wash the element according to the manufacturer's instructions and observe any wash limits the manufacturer places on the cleaner. Check after each washing for ruptures or cracks in the element and discard if noted.

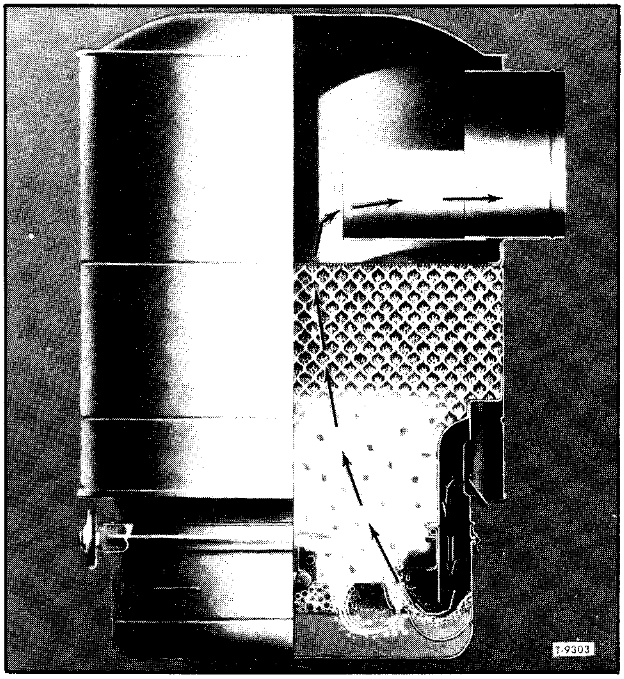
Just as important as adequate air to the cylinder is an acceptable flow of exhaust from the cylinder. An exhaust system can be overly restrictive when there are too many bends in the piping or when the pipe diameter or muffler are too small. High restriction can cause loss of horsepower due to the piston encountering increased pumping friction and can hamper the scavenging process which shows up as excessive exhaust smoke.

When conditions exist that indicate the need for an exhaust check, measure the back pressure with a mercury manometer at the exhaust manifold flange or within one inch of that location (both banks on V-engines).

NORMAL HEAT TRANSFER



Maintaining the engine cooling system in essence is insuring the efficient transfer of heat from the cylinder to the cooling system.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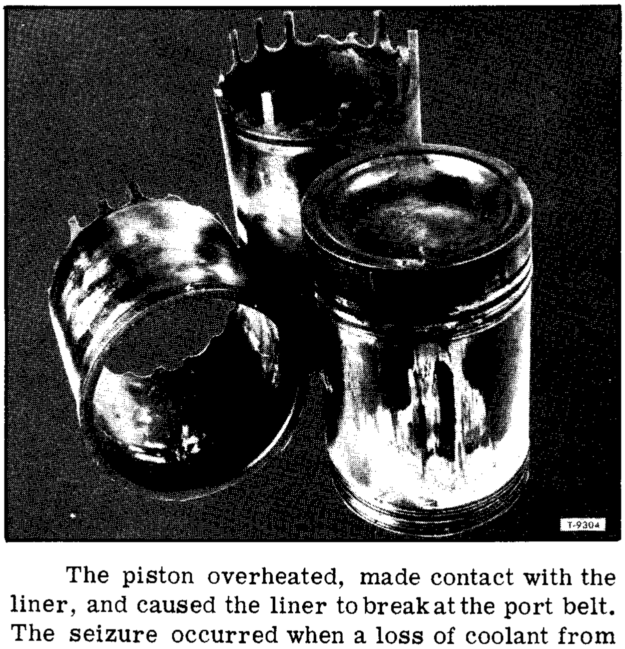
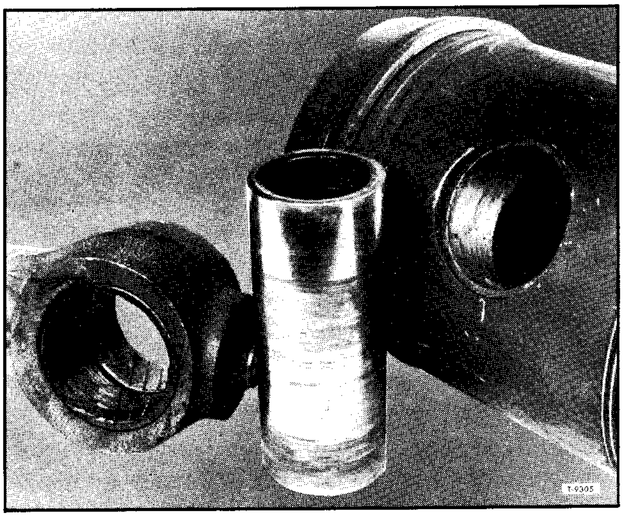
A leak (no matter how small) on the clean side of the air cleaner permits dirt to enter the system and speed ring, piston and liner wear.

PREVENTIVE MAINTENANCE FIGURES IN MOST CYLINDER COMPONENT PROBLEMS. . .SPECIFICALLY THE LACK OF IT

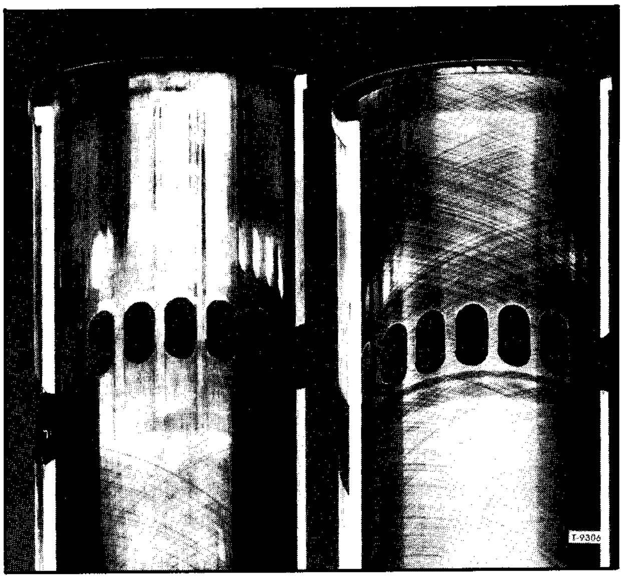
SOME EXAMPLES . . .


T-9304

The piston overheated, made contact with the liner, and caused the liner to break at the port belt. The seizure occurred when a loss of coolant from a leaking hose caused engine operating temperature to rise unnoticed above normal.


T-9305

The pin and its bushings overheated, and became scored when dirt in the lubricating oil blocked the drilled passage in the connecting rod and reduced oil flow to these components. The pin and bushings had to be replaced.


T-9306

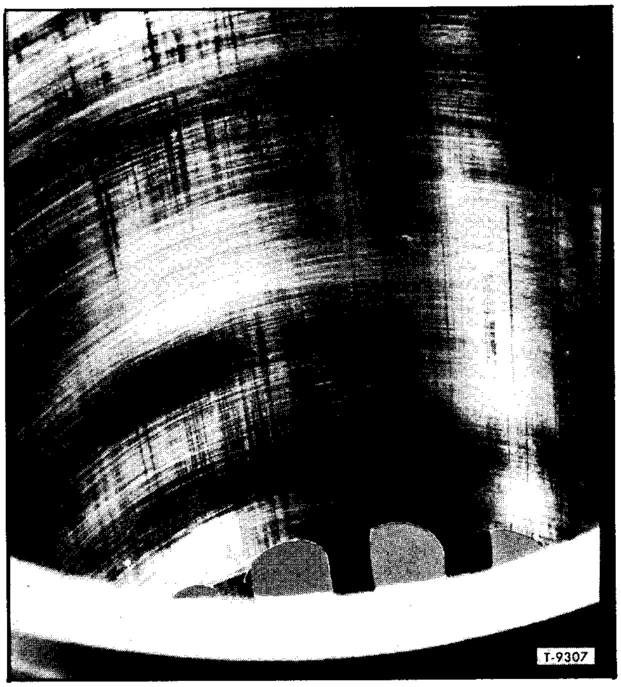
The liner (left) sustained extensive wear in an engine that was not getting properly filtered air. The liner (right), received normal wear for the same period, in an engine that received clean air through a properly maintained air intake system.

OTHER TROUBLE-MAKERS

MISMATCHED COMPONENTS

The fit of the liner to the cylinder block, the piston to the liner, the piston rings to the piston are critical to cylinder component life. The wrong oil control rings produce poor oil control.

Because the clearances between parts are measured in thousandths of an inch, the fitting together of cylinder components is best left to those trained and experienced in the job. It requires knowing the importance of checking the block bore, honing the liner, adhering to the proper measuring procedures, following the specifications on clearances and countless other details.



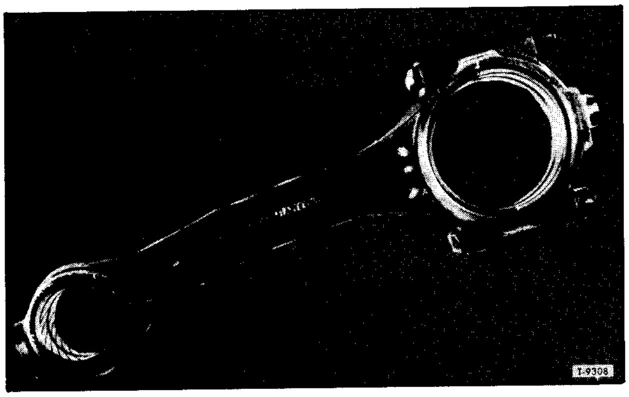
A poor honing job on this reworked liner made oil control on liner walls impossible and prevented piston rings from seating.

HYDROSTATIC LOCK

Hydrostatic lock can occur in the cylinder if water is trapped between the piston and cylinder head on the compression stroke. It occurs most often at initial engine startup following an overnight or prolonged shutdown. Hydrostatic lock accounts for a large pertentage of connecting rod mishaps.

Know what can cause hydrostatic lock and protect the engine accordingly. Hydrostatic lock can be caused by the entry of either water or fuel into the cylinder during shutdown. Water can enter from the exhaust manifold through an open exhaust valve, from a crack in the cylinder head or from a leaking injector tube.

Fuel lock is less common but it can occur from defective injector tips especially in engines that have high mounted fuel tanks.



Hydrostatic lock caused by water on the top of the piston bent this connecting rod.